RISK BASED ANALYSIS OF BEARGRASS CREEK, KY

By

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Background.

This paper summarizes the Louisville District's experiences in conducting a risk based analysis of flood damage reduction alternatives for the Beargrass Creek, basin in Metropolitan Louisville, Kentucky. The analysis conducted for Beargrass Creek was a feasibility level study. The Final Feasibility Report was completed in September 1997. In addition to the discussion of Beargrass Creek, a synopsis of the Louisville District's experiences with risk based analysis for a Continuing Authority study conducted under Section 205 of the 1948 Flood Control Act, and a 905(b) analysis, are presented.

The Louisville District's involvement with risk-based analysis for flood damage reduction studies began in January 1993, with the Indianapolis North, IN, Feasibility Study, which focused on the rehabilitation of existing levees and new levee construction. This was the first study conducted in the Louisville District where the concept of freeboard was not applied. At the time the Indianapolis North Feasibility Study was initiated, the District had little experience with using a risked-based analysis for flood damage reduction studies, and had several questions concerning the value added. Initial thinking was that the risk based analysis approach would require significantly more time, cost, and effort by the study team. The non-Federal sponsor for the Indianapolis North study, though supportive of the use of a risk-based analysis, expressed concern about potential increases in study cost. It appeared that, for the economist, a significant learning curve would be required to apply the risk-based approach. Some reluctance was due to the fact that the Louisville District had invested heavily in training at the Corps' Hydrologic Engineering Center (HEC) in the use of the Flood Damage Analysis (FDA) software. Beginning in the late 70's until the early 90's this was the economist's primary tool for flood damage analysis. Programs which were a part of the FDA package, such as EAD, SID, FDA2PO and other utilities were well documented, and supported by HEC.

Expertise was sought from the Hydrologic Engineering Center (HEC) and the Institute for Water Resources (IWR). Initially, a version of the @Risk spreadsheet which produced a stage-damage relationship with uncertainty was used for the analysis. Assistance was provided by IWR staff in developing probability distributions of the results of the risk based analysis. This occurred prior to the release of the Beta Test version of the FDA program now used by the District. Knowledge gained through application of the risk based analysis approach to the Indianapolis North Feasibility Study, was soon applied to other District flood damage analyses, such as Beargrass Creek, KY.

At present, based on it's success with studies such as Indianapolis North, the provisional, or Beta Test version of the HEC-FDA software is the Louisville District's primary tool for risk-based flood damage analysis for all studies. The HEC-FDA is now used by the District for all stages of study, from initial assessments, and 905(b) analyses, to feasibility level studies. Since the Indianapolis North study, the Louisville District has used a risk-based analysis approach for a total of nineteen studies.

The Louisville District has used risk-based analysis for Initial Assessments, as well as for more detailed decision documents. Current policy guidance requires a risk-based analysis only for decision documents. However, because the new release of the HEC-FDA is so efficient at handling the data input and interfaces between hydrologic engineering and economics, it makes sense to assess the uncertainties as early as possible, during the initial appraisal, or, if data is available, during conduct of the 905(b) analysis.

To date the HEC-FDA has been used for urban and agricultural studies, to evaluate the uncertainties inherent in the effectiveness of levees, detention basins, and channel modifications, stream diversion, and combinations of these structural alternatives. Risk-based analysis has also been used for an evaluation involving a major rehabilitation of a Corps of Engineers multipurpose reservoir. For this particular analysis, an event tree was developed to identify the probabilities and uncertainty associated with various failure modes. The probabilities of failure were used in the economic analysis to determine the impact on project outputs such as flood damage reduction, water supply, and recreation. The event tree was jointly developed by senior members of the study team, including geotechnical and hydraulic engineers, and economists.

Risk based analyses using the new program are routinely conducted for Continuing Authority Program studies conducted under Section 205, as well as expedited reconnaissance studies conducted under Section 905(b) of the Water Resources Development Act of 1996. The Lebanon Junction, Kentucky Section 205 study, and the Mill Creek, Kentucky, 905(b) analysis are two examples, and are discussed later in the paper.

Beargrass Creek, KY Feasibility Study

The Beargrass Creek feasibility study was conducted in partnership with the Louisville and Jefferson County Metropolitan Sewer District (MSD). MSD is responsible for the maintenance and improvement of storm water drainage facilities in Jefferson County, Kentucky.

The Beargrass Creek basin encompasses approximately 61 square miles. Approximately 50% of the City of Louisville, the largest city in the state, lies within the boundaries of the drainage area. Figure 1 depicts the drainage basin boundaries. Beargrass Creek originates in eastern Jefferson County, and flows through the north-central part of the county, into the Ohio River just east of Louisville's downtown business district. The South Fork, which is about 15 miles in length is considered the main stem. The Middle Fork tributary, also 15 miles in length, joins the South Fork about 1.5 miles above its mouth in downtown Louisville. Muddy Fork, approximately half the size of the other two streams, also joins the South Fork in downtown

Louisville, about one-half mile above its mouth. The feasibility study focused on the southern half of the Beargrass Creek drainage basin, where both the South Fork, and its tributary Buechel Branch, are located. The South Fork has one gaging station, located at stream mile 6.6. Buechel Branch is ungaged. For study purposes, the study area on South Fork was divided into 15 reaches, and Buechel Branch was divided into six reaches.

The Beargrass Creek basin is located in a highly developed area. The population approaches 2,500 people per square mile. Residences and businesses are built adjacent to the stream, particularly in the lower reaches. There are many multiple family residences within the study area. Parts of nineteen apartment complexes have buildings in the floodplain which are subject to flooding.

Development in the last two decades, particularly in the upper reaches of South Fork has resulted in additional rainfall run-off, and a corresponding increase in potential damage. The amount of development and hydrologic characteristics of the watershed are not expected to change significantly in the future.

Flooding from Beargrass Creek is among the top priority problem areas within Jefferson County. Flooding occurred in the basin in 1937, 1964, 1970, 1973, 1990, and in 1997. The flood of record is the March 1964 event, which resulted in the greatest 24 hour rainfall ever recorded in Louisville up to that point, 6.97 inches. Flooding from Beargrass Creek is caused by locally intense rainstorms. Flood waters from the streams generally rise rapidly, with little warning time, and have high velocities. In the upper reaches of the South Fork, the duration of flooding is generally between 25-45 minutes, once the water is out of bank. Expected depths of flooding on first floors of structures for a 1% chance event range up to 8.5' on South Fork and 3.1' on Buechel Branch.

Approximately 85% of the structures in the study area are residential. A 1% chance flood event along the South Fork would damage 759 structures, valued at $219,123,000, and would result in about $45,590,000 in damages. On Buechel Branch, a 1% chance flood would affect about 170 structures valued at $15,286,000, and would cause damage estimated at $2,812,000. A 10% chance flood would cause an estimated $6,803,000 in total damages on South Fork, and $890,000 on Buechel Branch. The expected annual damages (EAD) for the study area are $3,015,000.

Economic Analysis—Evaluation Tools.

Estimates of flood damages were based on surveys originally made during the 1993 Reconnaissance Study, and later updated for the Feasibility Study. Two different Flood Damage Analysis (FDA) packages were used to evaluate damages and benefits of proposed flood mitigation plans during the course of the study. During the early stages of the study, the Beta Test Version (NextGen) of the FDA software had not been widely released to the field for use. Therefore, the FDA package of computer programs developed in 1994 by the Corps' Hydrologic Engineering Center (HEC) was used to integrate hydrologic, hydraulic and economic data, and to compile initial screening level estimates of potential damage due to flooding. The 1994 version

of the software includes the Structure Inventory for Damage (SID) and Expected Annual Damage (EAD) programs. The SID component of the FDA software is used to estimate the number of structures flooded by various flood heights. The EAD program provides estimates of existing condition expected annual damage.

The 1994 release of the FDA software offered no capability for conducting a risk based analysis. Up to the release of the Beta Test Version of the FDA software, uncertainties were handled through the use of sensitivity analyses on such variables as interest rate, costs, and benefits.

One risk and uncertainty modeling tool available to the Louisville District during most of the Feasibility study was @Risk, a Lotus program which is used in conjunction with the FDA software. However, the large number of reaches and structures in the Beargrass Creek study area, combined with the large number of plans to be analyzed, precluded the use of this program to evaluate uncertainties. Screening of alternatives leading to identification of the National Economic Development (NED) plan, was therefore accomplished by estimating the expected annual damages and benefits with the EAD program. The existing EAD for South Fork and Buechel Branch, developed with the 1994 FDA software, is shown by category in Table 1.

In December 1996, the Beta Test, or provisional version of the new FDA software was released by HEC. This program provides a means for accounting for uncertainties in economic and hydrologic and hydraulic (H&H) estimates. This is done by use of statistical distributions and standard deviations as measurements of error for major input variables required to model flooding in a floodplain. An improvement of this program over the previous version of the FDA software is its ability to include all of the water surface profile data in its analysis instead of only that data at the index points. The program performs several thousand iterations of a Monte Carlo simulation to pick input values of variables based on the distributions and standard deviations of error specified.

The Beta Test Version of the software was used in the Beargrass Creek study as soon as it was available to the Louisville District, in July 1996. The major variables for which uncertainties were estimated included discharges and stages of flooding, structure first floor elevations, structure values, structure-to-content value ratios and depth-damage functions. The Beta version performs many iterations of damage estimates by randomly picking values for these variables with uncertainties described by the type of, and error in distributions. Iterations of this procedure are made for each reach until the change in the mean of the damage estimate is minimal. The mean damage estimated in this way is the expected annual damage. Index points in each damage reach are used as points to aggregate stage-damage for that reach. Though the Beta Test software was not used for initial screening of alternative plans for the Beargrass Creek study, it was used to evaluate the effectiveness of the final array of plans.

Risk Based Analysis Procedures.

Following is a description of how uncertainty in the major input variables described above was addressed in the Beargrass Creek Feasibility Study.

TABLE 1

Beargrass Creek Feasibility Study
Existing Condition Flood Damage ($000)
By Category and Flood Event
FY 1996 Price Levels

	Flood Event by Chance of Occurrence							
Stream/Category	**100%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.2%**
South Fork								
Single Family Residential	**0**	**11**	**489**	**1,764**	**3,024**	**5,276**	**7,021**	**13,814**
Multi Family Residential	**0**	**189**	**1,301**	**3,400**	**5,022**	**7.715**	**9,890**	**18,450**
Commercial	**0**	**4**	**59**	**474**	**1,337**	**3,170**	**17,762**	**69,562**
Public	**0**	**0**	**13**	**325**	**2,997**	**5,401**	**5,720**	**11,208**
Roads/ Utilities	**0**	**0**	**3**	**11**	**20**	**41**	**63**	**194**
Automobile	**0**	**2**	**151**	**685**	**1,248**	**2,366**	**4,416**	**9,218**
Emergency Costs	**0**	**0**	**30**	**144**	**218**	**299**	**388**	**674**
Traffic Diversion	**0**	**0**	**0**	**0**	**59**	**109**	**130**	**130**
Total	**0**	**206**	**2,045**	**6,803**	**13,925**	**24,377**	**45,590**	**123,237**
Buechel Branch								
Single Family Residential	**0**	**0**	**87**	**282**	**512**	**1,019**	**1,380**	**2,325**
Multi Family Residential	**0**	**42**	**409**	**533**	**685**	**828**	**925**	**1,154**
Commercial	**0**	**0**	**13**	**21**	**27**	**38**	**48**	**124**
Public	**0**	**0**	**0**	**6**	**16**	**29**	**33**	**39**
Roads/ Utilities	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Automobile	**0**	**0**	**1**	**18**	**45**	**112**	**166**	**412**
Emergency Costs	**0**	**0**	**17**	**30**	**46**	**65**	**68**	**72**
Traffic Diversion	**0**	**0**	**0**	**0**	**85**	**188**	**192**	**199**
Total	**0**	**42**	**526**	**890**	**1,416**	**2,279**	**2,812**	**4,325**

First Floor Elevations. Extensive field verification of structure inventory data gathered during the reconnaissance study was performed in 1995 and 1996. Detailed topographic field verification, changes in development in the floodplain were noted on the mapping, and included in the updated structure database. The 0.2% chance flood elevation was delineated on the maps to show areas and structures subject to flooding. First floor elevations of structures within the study area were estimated from the topography and spot elevations of the mapping.

The first floor elevations of a sample of 195 structures were verified by the District's Engineering Division, using land surveying instruments. The sample equated to 16% of the number of structures in the 0.2% chance floodplain. Elevations of the specific structures obtained using survey instruments were then used in the economic modeling, instead of the estimated values. The average of the absolute values of the differences between the estimated and surveyed first floor elevations for this sample was 0.62'.

Depth-Damage Estimates. Interviews were conducted with responsible parties for each non-residential property within the 1.0% chance floodplain, and for the larger properties located between the 1.0% and 0.2% floodplains. The damage estimates for non-residential categories reflected the high and low range of damages as well as the most likely damage for various levels of flooding, up to the depth of the 0.2% chance flood. This triangular distribution is not an active option for the economic portion of the current version of the FDA software, therefore, a method described in the draft Engineering Manual (EM) 1110-2-1619, dated March 1996, was used to estimate standard deviations of error for the damage estimates. This method takes into account the range between the maximum and minimum estimates of damage and assumes a normal distribution, and a 95% confidence interval.

Residential damage estimates were based on the Federal Emergency Management Agency's (FEMA) depth-damage functions (expressed as a percent) for structure and contents for various depths of flooding. The percent damage functions were first developed by the Corps of Engineers in 1973, and since 1978, have been updated by FEMA based on flood damage claims data. The dispersion statistics as measures of error in the residential damage functions are only available for actual claims data collected. Some structure types have the required number of claims needed for full credibility in the damage estimate at certain depths of flooding. For these estimates, the calculated standard deviation of error is equivalent to that for the depth-percent damage function used. However, values for most flood depths in the damage functions for the various structure types do not have sufficient claims data to achieve full credibility. In these cases, the standard deviation which was calculated for the actual claims data was still applied, because it was the closest proxy for this statistic for the values used.

Content and Structure Value. The Marshall & Swift Residential Cost Handbook was used to estimate the value of flood prone residential structures, both single and multi-family, in the study area. Estimates of error in values of residential structures were based on a range of typical accuracy provided by a representative of Marshall & Swift in a previous feasibility study. The content-to-structure value ratios used with the new FDA program are those provided for various structure types in EM 1110-2-1619. These are based on FEMA Flood Insurance Administration (FIA) claims data. Using this data, contents, as a percentage of structure value, range from

40.2% to 44.1%. Standard deviations of error were also provided in the EM for these ratios, and were used in this model.

Existing Condition Damages. The new FDA program uses the length of record of the gage, 56 years on South Fork, to calculate the standard deviations of error for exceedance probability-discharge relationships for hydrologic uncertainty. The hydraulic stage-discharge uncertainty was estimated to become constant at the 1.0% chance flood, at a standard deviation of error of 0.5'.

Existing condition flood damage, estimated with the new FDA program, with uncertainties of the major economic and hydrologic and hydraulic variables accounted for, is shown in Table 2.

TABLE 2

Beargrass Creek Feasibility Study
Existing Condition Flood Damage ($000)
By Category and Flood Event
(With Uncertainties Accounted For)
FY 1996 Price Levels

	Flood Event by Chance of Occurrence							
Stream/Reach/Category	**100%**	**50%**	**20%**	**10%**	**4%**	**2%**	**1%**	**0.2%**
South Fork								
Single Family Residential	**19**	**108**	**862**	**2,379**	**3,889**	**6,678**	**8,985**	**14,771**
Multi Family Residential	**113**	**302**	**1,747**	**4,530**	**7,118**	**11,966**	**16,152**	**27,575**
Commercial	**26**	**65**	**283**	**665**	**1,247**	**8,628**	**17,728**	**42,062**
Public	**0**	**1**	**68**	**969**	**2,040**	**3,706**	**4,435**	**5,775**
Roads/ Utilities	**0**	**0**	**4**	**13**	**22**	**49**	**77**	**151**
Automobile	**5**	**22**	**306**	**813**	**1,305**	**2,669**	**4,222**	**9,144**
Emergency Costs	**3**	**7**	**44**	**115**	**181**	**360**	**537**	**1,027**
Traffic Diversion	**0**	**1**	**6**	**19**	**33**	**62**	**86**	**160**
Total	**166**	**506**	**3,320**	**9,500**	**15,835**	**34,118**	**52,222**	**100,665**
Buechel Branch								
Single Family Residential	**5**	**18**	**107**	**418**	**777**	**1,278**	**1,586**	**2,102**
Multi Family Residential	**17**	**94**	**405**	**639**	**761**	**922**	**1,023**	**1,184**
Commercial	**0**	**1**	**13**	**21**	**28**	**42**	**55**	**82**
Public	**1**	**2**	**5**	**14**	**21**	**28**	**31**	**36**
Roads/ Utilities	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Automobile	**1**	**5**	**20**	**30**	**35**	**43**	**47**	**55**
Emergency Costs	**0**	**2**	**12**	**33**	**53**	**83**	**104**	**140**
Traffic Diversion	**1**	**7**	**38**	**84**	**127**	**190**	**230**	**296**
Total	**25**	**128**	**600**	**1,239**	**1,803**	**2,586**	**3,076**	**3,895**

Note that damage estimated when including uncertainties oftentimes begins in different flood zones than when estimated without uncertainties accounted for, as with the original FDA software. Uncertainties in first floor stages of structures and in hydrologic frequency curves and rating curves often indicate the possibility of damage at more frequent events. The total expected annual damage estimate, with uncertainties estimated using the Beta Test program was higher than that of the original FDA software. This difference in EAD estimated with the newer release program and with the original FDA software was also noted in other flood damage analyses conducted by the District.

Evaluation of Flood Reduction Plans. During the screening process, a number of flood damage reduction measures were evaluated. Those that were studied included: Without Project Condition/No Action, Reservoirs, Detention Basins, Channel Modification, Levees and Floodwalls, and Bridge Modifications. As stated, economic evaluation was performed with risk and uncertainty analysis with the Beta Test program beginning with the screening of the final array of plans.

The current FDA program requires eight water surface profiles. Prior to receipt of the software, hydrologic information was supplied for flood events with exceedance frequency values of 50%, 20%, 10%, 4%, 2%, 1% and 0.2% chance of occurrence. Because of the requirements of the current program, the H&H analysis for the last nine flood damage reduction plans evaluated included hydrologic information for the 100% chance flood profile. The final nine plans were evaluated with both FDA programs, with and without uncertainties considered. When this was done, the size and design which yielded maximum net benefits for two of the major project components, a detention basin, and channel modification, was the same with both programs. The inclusion of uncertainties in the analysis did not change formulation for these components.

The recommended plan consisted of ten components, eight of which are detention basins. An I-Wall/Levee, and channel modification are also part of the recommended plan. A summary of residual damage, estimated with the EAD program, and percent reduction of damage with the NED plan, is presented in Table 3, and is also shown with uncertainties accounted for in Table 4.

TABLE 3

Beargrass Creek Feasibility Study
Expected Annual Damage and Benefits
With and Without NED Plan
FY 1996 Price Levels ($000)

Stream	Expected Annual Damage Without Plan	Expected Annual Damage With Plan	Benefits	Percent Reduced
South Fork	2,705	844	1,861	68.8%
Buechel Branch	310	93	217	79.0%
Total Study Area	3,015	937	2,078	68.9%

Note: Expected annual damage and benefits shown were estimated with the EAD program, not accounting for uncertaintie

TABLE 4

Beargrass Creek Feasibility Study
Expected Annual Damage and Benefits
With and Without NED Plan
(With Uncertainties Accounted For)
FY 1996 Price Levels ($000)

Stream	Expected Annual Damage Without Plan	Expected Annual Damage With Plan	Benefits	Percent Reduced
South Fork	3,587	1,572	2,015	56.2%
Buechel Branch	411	112	299	72.7%
Total Study Area	3,998	1,684	2,314	57.9%

Note: Expected annual damage and benefits shown were estimated with the NextGen FDA program, which accounts for uncertainties.

Table 5 presents expected values with associated probabilities for expected annual benefits, net benefits, and benefit-to-cost ratios for the recommended NED plan.

Table 5

Beargrass Creek Feasibility Study
Economic Analysis With
With Recommended NED Plan
FY 1996 Price Levels ($000)

Probability of Value	Expected Annual Benefit Exceeds	Net Benefit Exceeds	Benefit-to-Cost Ratio Exceeds
Expected	2,314	1,504	2.86
0.75	1,365	555	1.69
0.50	2,071	1,261	2.56
0.25	3,054	2,244	3.77

Lebanon Junction, Kentucky

Lebanon Junction, Kentucky is located in southern Bullitt County about 25 miles from Louisville, and is shown in Figure 2. A levee was constructed by the Corps in 1966 to reduce frequent flooding from the Rolling Fork river. The existing project consists of a 4,175' long earth levee constructed to an elevation of 450' msl, with three drainage structures. Since the levee was constructed, Lebanon Junction has been flooded four times. Flooding occurred as a result of flow entering the town at the low area, where the top of the levee is elevation 447' msl.

A Draft Detailed Project Report was prepared in 1990 to report the findings of a feasibility level evaluation of increasing the level of protection provided by the existing project. The Recommended Plan at that time, consisted of raising the existing levee to elevation 451. Due to lack of local sponsor funding the feasibility study was suspended in 1990. The feasibility study was resumed in 1996. The initial focus of the study was on re-evaluation of the 1990 plan. In March 1997, a storm entered the Louisville area which exceeded rainfall records. Former record rainfall of 7-8 inches was surpassed with 12-13 inches of rainfall in a 24-30 hour period. The storm affected the Lebanon Junction study area. Until March 1997, floodwaters had not been recorded above elevation 451' msl in Lebanon Junction. As a result of the March 1997 event, the existing levee was overtopped. High water marks were recorded at elevation 452' msl. As a result of the flood, the design of the recommended plan, this time based on a risk based analysis, was changed to increase the effective levee protection to elevation 453'.

The 1990 study was not conducted using a risk-based analysis. The levee was designed using the concept of freeboard. The current analysis, with the new HEC-FDA utilized some of

the original economic study data, and incorporated risk and uncertainty. Table 8 presents output from the new HEC-FDA related to the project performance. As can be observed from Table 6, the Recommended Plan still has considerable long term risk. However site constraints preclude the levee height exceeding elevation 453'.

The risk associated with the proposed levee being overtopped was presented to the mayor and community in September 1997. Data from Table 6 was used to brief the City on the risk associated with project performance. The City of Lebanon Junction has to date indicated a continued interest in participating in construction of the $1.3 million dollar project to upgrade the existing levee.

Mill Creek, Kentucky.

The Mill Creek, Kentucky expedited reconnaissance study is an example of an analysis conducted under the 905(b) guidance. The Mill Creek study area is in the southwest portion of Jefferson County, in metropolitan Louisville, Kentucky (see Figure 3). The economic analysis was conducted in about two weeks at a cost of approximately $3,000, and used the current FDA software. Because of the efficiency of using the current program, the District made the decision to used a risk based approach whenever possible. In the case of Mill Creek, existing Geographic Information System (GIS) data was available from the local sponsor, and was easily interfaced with the FDA program. GIS data, including addresses, structure locations by stream mile, structure value, property type and other information was provided. There were about 800 structures in the 1% chance flood with expected annual damages of over $600,000. The 905(b) analysis was recently approved as a basis for developing the Project Study Plan.

Table 6

Expected Annual Performance and Equivalent Long-term Risk With Existing and Proposed Options Lebanon Junction Kentucky Rolling Fork

		Equivalent Long-term Risk Chance of Exceedance during		
Levee Plan	Annual Chance of Design Being Exceeded	10 Years	25 Years	50 Years
Existing Levee	11.6%	71.0%	95.5%	99.8%
Option 1(451')	3.4%	29.4%	58.1%	82.5%
Option 2(453')	1.9%	17.4%	37.9%	61.4%
Option 3(454')	1.4%	13.0%	29.4%	50.2%
457.8	0.3%	2.6%	6.4%	12.3%

Conclusion. These three studies represent a diverse spectrum of effort, from an expedited reconnaissance level investigation, to a General Investigation Feasibility Study with multiple flood damage reduction alternatives. In each instance, the incremental cost for conducting the risk based analysis was minimal. The economic analysis for a Section 205 Study generally accounts for about 10-15% of the total study cost. That percentage is very comparable to the cost of the evaluation before the requirement for conducting the risk based analysis.

Fortunately the Louisville District has gained experience in preparing reports including a risk-based analysis, and can focus less on the mechanics of using the software, and more on gathering data in a risk-based framework. Experiences with the original FDA software has highlighted the importance of communication and close coordination with other disciplines on the team, primarily Hydrology and Hydraulics and Geotechnical Engineering. Continued coordination with HEC on application of the software is also critical. The challenge lies in interpreting the results and conveying them in a meaningful manner to the project sponsors, and affected public. Table 7 presents the listing of the nineteen flood damage reduction studies conducted by the Louisville District using risk based analysis.

Table 7

Risk-based Analysis
By the Louisville District

Index	Study Name	Project Feature	Study Area/Type	Latest Study Report	Date of Study	Project Status	Risk-Based Software/Other
1	Rushville, IN	Levee	Urban/CAP	Feasibility/Positive	May-96	P & S	HEC and IWR @Risk Spreadsheets
2	SW Louisville, KY	Combined Sewer/Ponding	Urban/GI	Reconnaissance/Positive	May-96	Begin FR Jan 98	SWMM/GIS/NexGen HEC-FDA for FR
3	Metro Indianapolis	Rehabiltate/Raise Existing Levee	Urban/GI	Feasibility/Positive	Sep-96	Start FY 98	HEC and IWR @Risk Spreadsheets
4	Silver Grove, KY	Levee	Urban/CAP	Initial Assessment	Sep-96	Awaiting Approval	NexGen HEC-FDA
5	Gunpower Creek, KY	Detention Structures	Urban/CAP	Initial Assessment/Negative	Sep-96	Provide Tech Assist.	NexGen HEC-FDA
6	Jackson, KY	Stream Diversion	Urban/CAP	Feasibility/Positive	Oct-96	P & S/RE Acquisition	HEC and IWR @Risk Spreadsheets
7	Mill Creek, KY	Detention/Levee/Channel Mod.	Urban/GI	905b/Positive	Aug-97	Awaiting Approval	NexGen HEC-FDA/GIS
8	Patoka Lake	Spillway Repair of USCE Lake	Major Rehab	Major Rehab	Sep-97	P & S/FY 98	Event Tree
9	Beargrass Creek	Detention/Levee/Channel Mod.	Urban/GI	Feasibility/Positive	Oct-97	In Review	NexGen HEC-FDA
10	Birds, ILL	Levee	Urban/CAP	Initial Assessment/Positive	Sept-97	Awaiting Approval	NexGen HEC-FDA
11	Bridgeport, ILL	Channel Modification	Urban/CAP	Initial Assessment/Negative	Sept-97	Completed	NexGen HEC-FDA
12	Sumner, ILL	Channel Modification	Urban/CAP	Initial Assessment/Negative	Sept-97	Completed	NexGen HEC-FDA
13	Standford, KY	Detention Structures & Channel Mod.	Urban/CAP	Initial Assessment/Positive	Sept-97	Awaiting Approval	NexGen HEC-FDA
14	Panther Creek, KY	Detention Structures	Agriculture-Urban/GI	905b/Positive	Aug-97	Awaiting Approval	Lotus Spreadsheet/ NexGen HEC-FDA
15	Anderson, IN	Rehabiltate/Raise Existing Levee	Urban/CAP	Initial Assessment	Aug-97	Awaiting Approval	NexGen HEC-FDA
16	Mill Creek, OH	Levees/Channel Modification	Urban/GI	GRR	Oct-97	Awaiting Funding	NexGen HEC-FDA/GIS
17	Lebanon Junction, KY	Rehabiltate/Raise Existing Levee	Urban/CAP	Feasibility/Positive	Nov-97	Ongoing	NexGen HEC-FDA
18	Lexington, KY	Channel Modification	Urban/GI	Reconnaissance/Positive	May-97	In Review	NexGen HEC-FDA
19	Greenfield Bayou	Rehabiltate/Raise Existing Levee	Agriculture/GI	Feasibility/Negative 1/	Apr-98	Ongoing	@Risk Spreadsheet/ NexGen HEC-FDA

1/ Positive Environmental Restoration Feature

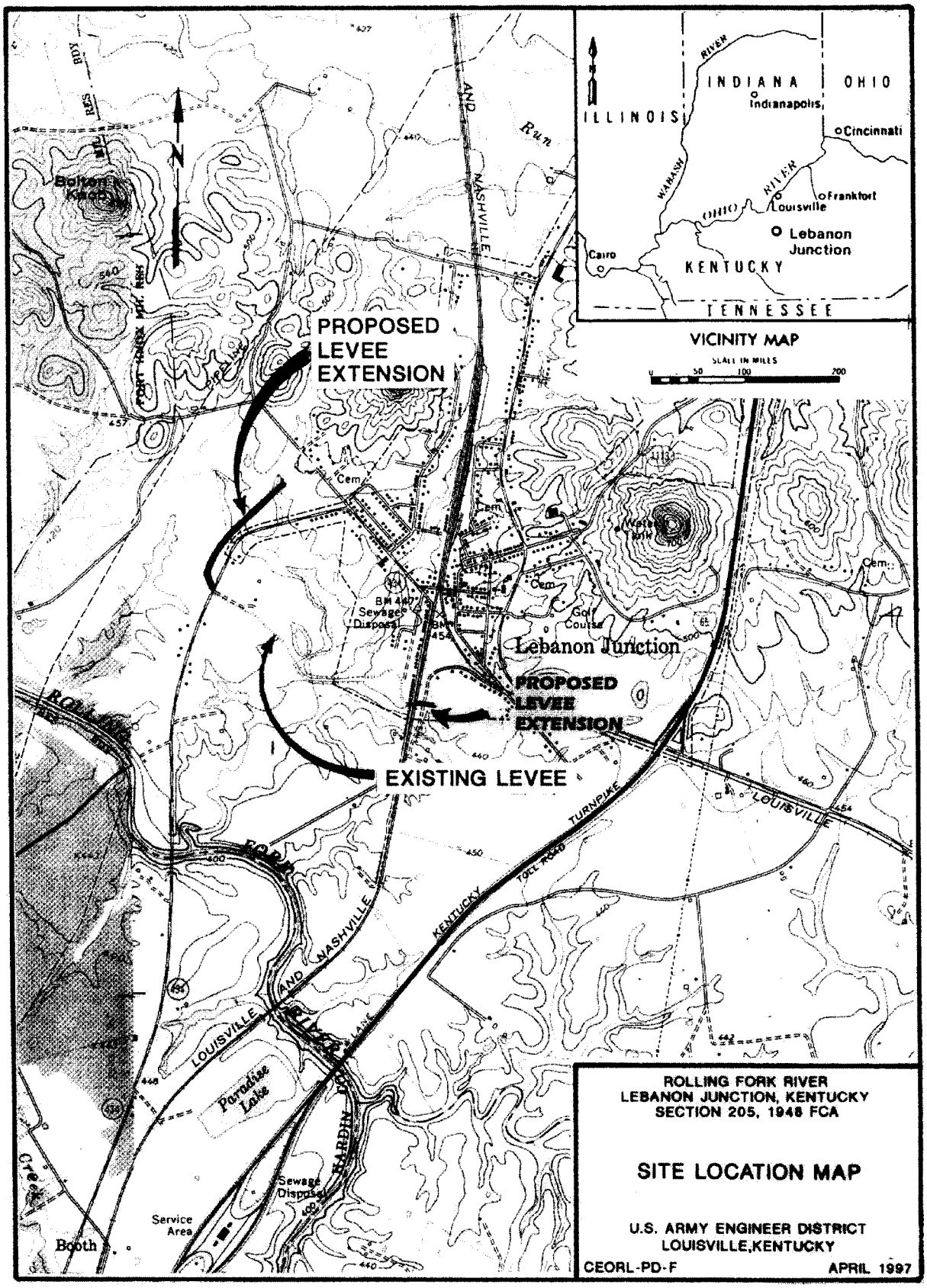
PROPOSED
LEVEE
EXTENSION
EXISTING LEVEE
PROPOSED
LEVEE
EXTENSION
Lebanon Junction
INDIANA
OHIO
ILLINOIS
Indianapolis
Cincinnati
Frankfort
Louisville
Lebanon
Junction
Cairo
KENTUCKY
TENNESSEE
VICINITY MAP
SCALE IN MILES
0 50 100 200
ROLLING FORK RIVER
LEBANON JUNCTION, KENTUCKY
SECTION 205, 1948 FCA
SITE LOCATION MAP
U.S. ARMY ENGINEER DISTRICT
LOUISVILLE,KENTUCKY
CEORL-PD-F
APRIL 1997

Figure 1

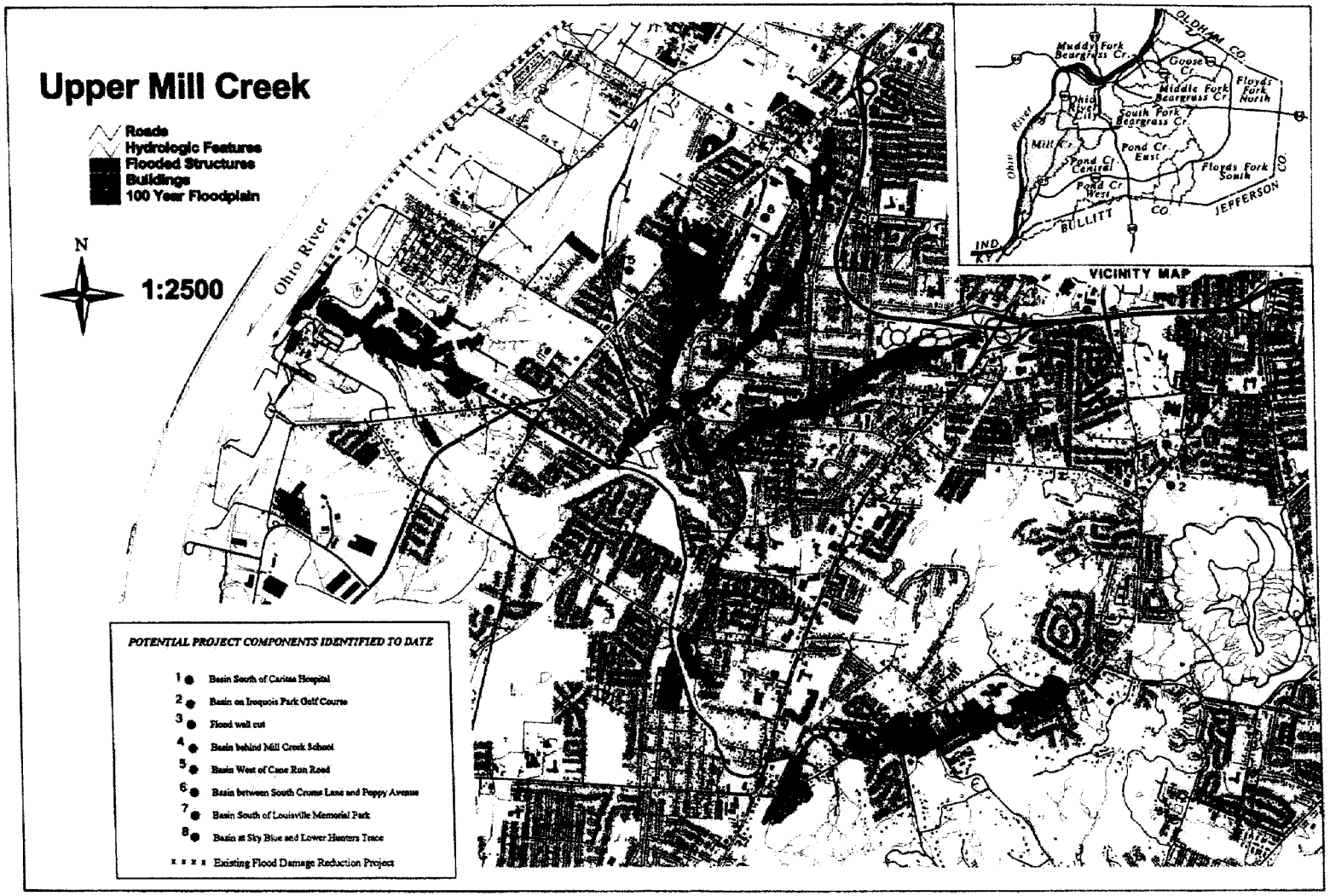
Upper Mill Creek
Roads
Hydrologic Features
Flooded Structures
Buildings
100 Year Floodplain
N
1:2500
Ohio River
VICINITY MAP
Muddy Fork Beargrass Cr.
Goose Cr.
Middle Fork Beargrass Cr.
Floyds Fork North
Ohio River City
South Fork Beargrass Cr.
Mill Cr.
Pond Cr. East
Pond Cr. Central
Floyds Fork South
Pond Cr. West
OLDHAM CO.
BULLITT CO.
JEFFERSON CO.
IND.
POTENTIAL PROJECT COMPONENTS IDENTIFIED TO DATE
1 Basin South of Caritas Hospital
2 Basin on Iroquois Park Golf Course
3 Flood wall cut
4 Basin behind Mill Creek School
5 Basin West of Cane Run Road
6 Basin between South Crums Lane and Poppy Avenue
7 Basin South of Louisville Memorial Park
8 Basin at Sky Blue and Lower Hunters Trace
Existing Flood Damage Reduction Project

Figure 2

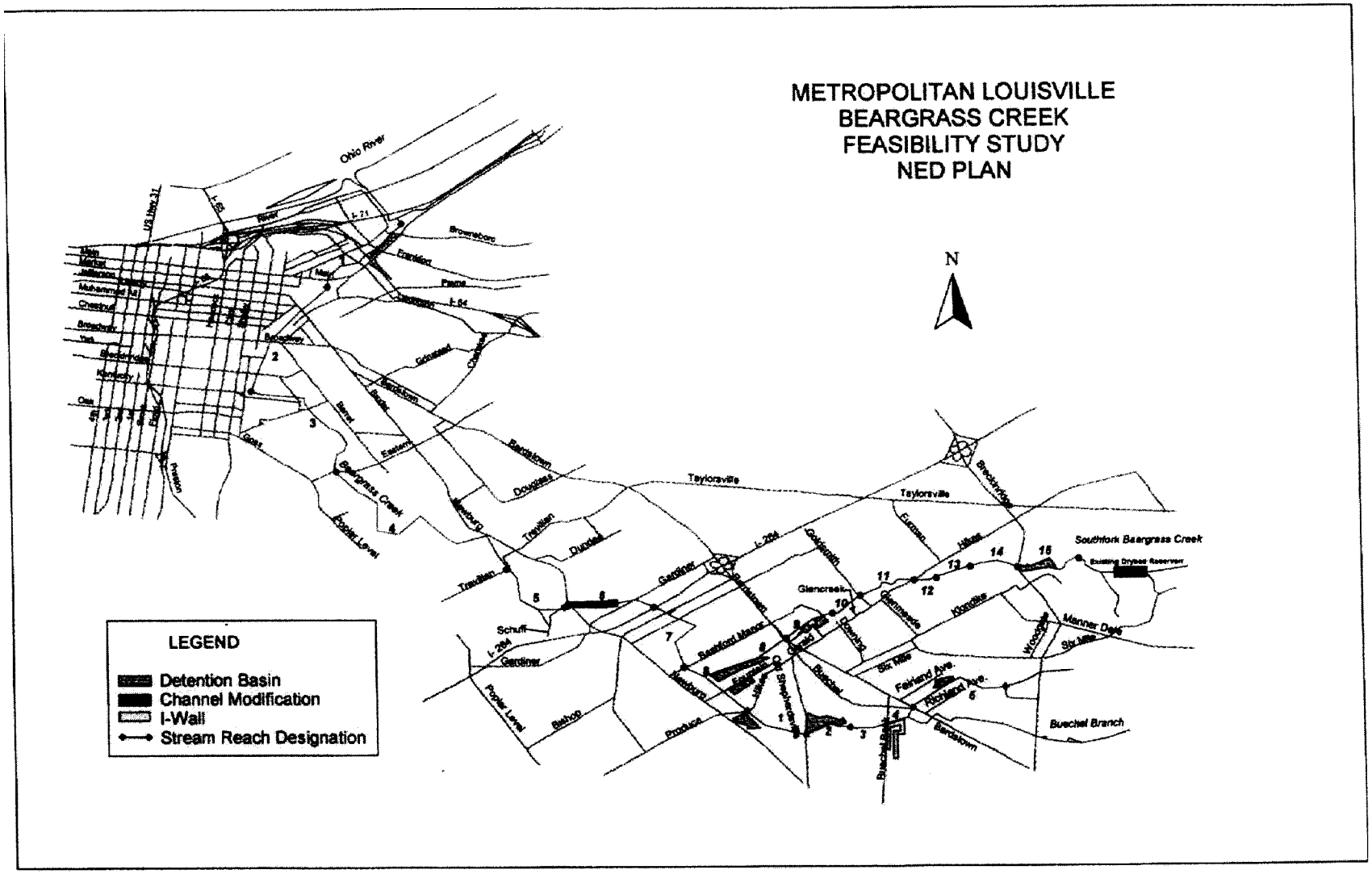
METROPOLITAN LOUISVILLE
BEARGRASS CREEK
FEASIBILITY STUDY
NED PLAN
N
LEGEND
Detention Basin
Channel Modification
I-Wall
Stream Reach Designation
Ohio River
Taylorsville
Southfork Beargrass Creek
Buechel Branch

Figure 3